PUBLIC HEALTH AIR POLLUTION IMPACTS OF PATHWAY OPTIONS TO MEET THE 2050 UK CLIMATE CHANGE ACT TARGET – A MODELLING STUDY

By

Martin L. Williams[1], Sean Beevers[2], Nutthida Kitwiroon[2], David Dajnak[2], Heather Walton[2,3] Melissa C. Lott[4], Steve Pye[4], Daniela Fecht[5], Mireille B. Toledano[4], Mike Holland[6]

[1] Lead author and corresponding author; email martin.williams@kcl.ac.uk, telephone +44(0)207 848 3844; address Environmental Research Group, King's College London, 150 Stamford Street, London SE1 9NH, UK
[2] King's College London, UK
[3] NIHR Biomedical Research Centre at Guy's and St Thomas' NHS Foundation Trust and King's College London, NIHR Health Protection Research Unit on Health Effects of Environmental Hazards, UK.

[4] University College London, UK.
[5] Imperial College London, UK.
[6] EMRC, UK

Important

A 'first look' scientific summary is created from the original author-supplied summary once the normal NIHR Journals Library peer and editorial review processes are complete. The summary has undergone full peer and editorial review as documented at NIHR Journals Library website and may undergo rewrite during the publication process. The order of authors was correct at editorial sign-off stage.

A final version (which has undergone a rigorous copy-edit and proofreading) will publish as part of a fuller account of the research in a forthcoming issue of the Public Health Research journal.

Any queries about this 'first look' version of the scientific summary should be addressed to the NIHR Journals Library Editorial Office – journals.library@nihr.ac.uk

The research reported in this 'first look' scientific summary was funded by the PHR programme as project number 11/3005/13. For more information visit https://www.journalslibrary.nihr.ac.uk/programmes/phr/11300513/#/

SCIENTIFIC SUMMARY

Background

The UK Climate Change Act (CCA) 2008 requires a reduction of 80% in Carbon dioxide (CO_2) -equivalent emissions relative to 1990. This large reduction offers the opportunity to make large reductions in air pollution and their impacts on public health. But not all pathways to the target will be equally 'clean' in air pollution terms. This project improves on previous impact calculations and develops a comprehensive system to explore some pathways and calculate their impact on public health.

Objectives

The objectives of the work as set out in the original proposal were:

-To develop a series of policy pathways to achieve the Climate Change Act 2050 target, spanning a maximum health benefit scenario at one extreme and a scenario that rejects the 2050 target at the other. In between these we will identify up to three scenarios which deliver increasingly large benefits for public health.

-On the basis of these scenarios, to produce air pollution emissions estimates for the UK and Europe, for 2050.

- To evaluate the air quality model for the current year and to establish the contribution to concentrations of particulate matter, nitrogen dioxide and ozone from sources within the UK and in Europe. These pollutants are the ones for which concentration-response functions are available to allow health impact assessments.
- To forecast air quality across the UK, including detailed modelling in urban areas for the future year and for the chosen policy scenarios.
- To calculate exposures at 9km x 9km resolution for the UK and at 20m x 20m resolution in major cities and to calculate personal exposures using the hybrid time-activity model.
- To calculate the impacts of the alternative future policies on mortality (and morbidity) using the life table approach and the associated monetary values.
- To assess the impacts of the different climate and air quality scenarios on UK health inequalities in the future years.
- Optimal strategies for maximising the public health benefits of achieving the Climate Change Act target for 2050 will be produced.

The original intention was to use the simple spreadsheet ‘Calculator’ produced by DECC (the former Department for Energy and Climate Change). However in the course of the project we formed a collaboration with University College London who run the energy model, UK TIMES (UKTM), as used by government and by the Committee on Climate Change (CCC) to formulate strategies to attain the CCA target. We felt that the more detailed UKTM model would give results with greater rigour as well as consistency with UK Government analyses. However, this added to the complexity of the modelling system, and we found that converting the UKTM national output into a spatially resolved air pollution emission inventory is a lengthy process. This reduced the number of 2050 scenarios we could model compared with the original objective, although we found $PM_{2.5}$ and PM_{10} emissions peak between now and 2050, and so runs were undertaken in 2035, not originally part of the project.

Methods

The UKTM model was used to develop four future scenarios; the ‘Baseline’ scenario was consistent with the Fourth and Fifth Carbon Budgets produced by the CCC and envisaged no further climate measures beyond those currently agreed. Two other scenarios achieved the CCA target with two differing levels of nuclear power. The Nuclear Replacement Only or ‘NRPO’ scenario assumed that only existing nuclear plant would be replaced and the low greenhouse gas scenario or ‘LGHG’ had no policy constraint on nuclear, limiting build only by economic and technical feasibility. Another scenario (the ‘Reference’) was identical to the Baseline except it contained a carbon price (£30 per tonne) to produce a scenario where some action was taken to reduce carbon emissions despite CCA targets for 2050 not being achieved. We reported emissions for the Reference scenario but it differed little from the Baseline so we did calculate the health impacts.

The sectoral fuel use outputs from UKTM were then converted into a 1km x 1km grid of air pollution emissions across Great Britain for each scenario. The pollutants considered for quantification of health impacts are fine particles ($PM_{2.5}$), nitrogen dioxide (NO_2) and ozone. These are the pollutants for which evidence of impacts is strongest.

The emission inventories were then used to run an air quality model, CMAQ. This has enabled us for the first time in GB to model air quality *concentrations* and their impacts on health rather than relying simply on *emissions* and generalised relationships between the latter and damage costs, as previous studies in this area have done. The outputs from

CMAQ went beyond those originally planned giving concentrations across GB at a spatial resolution of 10km in rural areas and 2km in urban areas. We also performed calculations at a spatial resolution of 20m in urban areas. This resolution is more likely to identify pollution ‘hot spots’ than coarser grids and is the first time concentrations at this resolution have been reported in GB.

The concentrations were used to calculate health impacts using well-known life table calculations but with the most recent coefficients (and confidence intervals) relating pollution concentrations to health outcomes as recommended by the World Health Organisation (WHO) or by the UK Committee on the Medical Aspects of Air Pollutants (COMEAP) for $PM_{2.5}$, NO_2 and ozone. We also assessed the differences in exposure to air pollutants in different socio-economic classes using the Carstairs index of deprivation.

Results

Scenario emissions

The two ‘CCA compliant’ scenarios, NRPO and LGHG, had a high proportion of energy generated through biomass use (wood burning) with a large increase in $PM_{2.5}$ emissions of approximately 50%, compared with 2011, and peaking in 2035. Although the biomass use was projected to decrease again by 2050, primary $PM_{2.5}$ emissions in 2050 were still marginally higher than 2011 levels. The Baseline and Reference scenarios, which did not meet the CCA target, had lower levels of wood burning.

Both the LGHG and the NRPO had a high degree of switching from petrol and diesel fuels to electric, hybrid and alternatively fuelled vehicles in the UK road transport fleet leading to reductions of around 90% from transport sector NO_x emissions in all scenarios except the Baseline. The Baseline scenario had higher gas and biomass consumption in Combined Heat and Power plants (CHP) compared to other scenarios as well as no obligation to meet the CCA target and this lead to increased NO_2 exposure. In the transportation sector, despite the exhaust emission reductions, the UKTM projections show large increases in traffic activity with car and HGV vehicle-kilometres projected to increase by roughly 50% in all the scenarios and vans by a factor of about two. This has lead to a pro-rata increase in PM emissions from brake and tyre wear and resuspension of road dust, although these are uncertain since we have assumed in future that the emissions factors will remain at current levels. Consequently, non-exhaust emissions could be the dominant source of primary PM from vehicles in future, increasing PM_{10} by about 15% compared with 2011 in the NRPO scenario for example. This is more of an issue for PM_{10}, as the non-exhaust emissions are coarser in size.

Pollutant concentrations

Annual mean concentrations of NO_2 are projected to decrease by more than ~60% in the LGHG scenario and by ~50% in the NRPO scenario across the whole of GB and in London, but only by ~20% across GB and ~42% in London in the Baseline scenario.

Annual mean $PM_{2.5}$ concentrations are also projected to fall by around 40% in the top 25% of grid squares but by only ~25% in the highest areas. However, concentrations of primary $PM_{2.5}$ are projected to increase in 2035 in the NRPO and LGHG scenarios, by around 30%-60% in the more polluted grid squares, as a result of the increase in biomass use. By 2050 in those two scenarios, levels are only slightly smaller than 2011 values and in the highest grid square very similar to 2011 concentrations. If this amount of primary $PM_{2.5}$ were to be removed, by avoiding the high use of biomass, total $PM_{2.5}$ concentrations could fall even further than projected, down by ~50% in the highest areas compared with ~25% reduction with the increased biomass use.

Total PM_{10} concentrations are projected to increase in 2035 in many areas of the UK in both the LGHG and NRPO scenarios, despite the reduction in secondary PM precursors, due to the increased use of biomass and the increased non-exhaust emissions from transport. PM_{10} levels decrease again by 2050 but remain only about 15% smaller than 2011 in the more polluted areas of GB. This is a small reduction and is not larger due to the increasing contribution from non-exhaust emissions. This is of concern as these emissions are potentially toxic.

The reductions in NO_x emissions result in increasing annual average ozone concentrations in urban areas, leading to higher exposures using the metric recommended by COMEAP for short term impacts on mortality. In contrast, all scenarios show reductions in the metric suggested by WHO for long-term ozone exposure impacts on mortality.

Both ozone and NO_2 are strong oxidizing agents and can play a role in oxidative stress in the human body. This can be quantified through the use of the metric O_x or oxidant (O_x = O_3

+ NO_2) which has been shown to be associated with adverse health outcomes. Annual average levels are projected to remain virtually constant to 2050. The significance of this for health is that the balance of O_x will shift to ozone as NO_2 reduces; the former is the more powerful oxidant so that the oxidizing power of the urban atmosphere in the UK will increase with potentially increased adverse health effects, assuming the global background of ozone remains broadly constant.

Health impacts

We have calculated impacts arising from long-term exposures to the pollutants $PM_{2.5}$, NO_2 and ozone, on mortality, using a life table approach to calculate the loss of life years in each of the scenarios. This now incorporates birth projections, projected improvements in mortality rates, and mortality rates at local authority level. The two scenarios which achieve the CCA target result in more life years lost from long-term exposures to $PM_{2.5}$ beyond the carbon policies already in place and the levels of $PM_{2.5}$ still result in a loss of life expectancy from birth in 2011 of around 4 months. This is an important opportunity lost and arises from the large increase in biomass use peaking in 2035. Our estimates suggest that in the more highly polluted areas of GB, total $PM_{2.5}$ concentrations could reduce by as much as 50% without the biomass contribution.

There is currently some uncertainty over the role of the NO_2 contribution to the concentration-response function compared with $PM_{2.5}$ and other pollutants, but using the concentration response functions currently suggested by COMEAP, reduced long-term exposures to NO_2 lead to more life-years saved and an improvement of 2 months in loss of life expectancy from birth in 2011 in the 'CCA compliant' scenarios compared with the Baseline scenario, with the largest benefits arising from the most ambitious scenario LGHG. Due to the uncertainties around NO_2, we have not suggested adding the impacts for the different pollutants nor do we consider the NO_2 benefits cancel out the adverse health impacts shown for $PM_{2.5}$, where the health evidence is stronger.

Evidence for impacts on mortality of long-term exposures to ozone is increasing although using the quantification recommended by WHO we estimate life years lost from this exposure to be smaller by factors of ~6 and ~3-4, than those from $PM_{2.5}$ and from NO_2, respectively, if no threshold is assumed for NO_2. However, the short-term ozone exposure metric recommended by COMEAP suggests the number of deaths brought forward in a year could be around 22,000 compared with 29,000 from long term $PM_{2.5}$ exposures.

We also investigated the effect of the changing concentrations on exposures in different socio-economic classes. We observed differences in air pollution levels in subpopulations for all analysed pollutants and for each geographical area. Differences in exposure were most marked for NO_2 for ethnicity and for socio-economic deprivation. Wards with higher proportions of Non-White residence and higher deprivation are expected to be closer to roads and therefore exposed to these higher NO_2 levels. The ratios of exposures in White and Non-white populations were much larger than those for the most deprived populations, compared to least deprived populations in GB and Wales, but slightly smaller in London. Relative differences between most and least deprived populations were highest in Scotland closely followed by London; relative differences in Wales were the smallest.

All future scenarios reduced the absolute levels of pollution exposure in all deprivation quintiles across GB, except in those cases where there is a large increase in biomass burning. Differences in exposure between the most and least deprived populations remain in all scenarios, most clearly for NO_2, where there is little difference between the Baseline scenario and the NRPO scenario.

Conclusions

There are several important conclusions which arise from this work. The CCA target in principle offers a great opportunity to make very large reductions in air pollution emissions as the UK energy system is decarbonised. However, the $PM_{2.5}$ emissions from the large increases in biomass use and the increase in non-exhaust PM emissions from transport in the two CCA-compliant scenarios we have studied mean that $PM_{2.5}$ and PM_{10} concentrations do not reduce as much as they might otherwise have done. One option to improve air quality impacts on health would be to discourage the use of biomass in small installations, or to increase the stringency of the emission limits in the Eco Design Directive. Further research could investigate other possible scenarios which could avoid the problem with biomass use. Further research is also required on the toxicity of primary PM as well as other components of airborne particles.

PM_{10}, and to a lesser extent $PM_{2.5}$, non-exhaust emissions are projected to increase significantly by 2050 as traffic activity increases. The precise agents in tyre and brake wear and resuspended dust responsible for the potential toxicity of these emissions are as yet unclear so reformulation of these products would need to await more clarification from toxicological research. However, in the meantime, one solution here is to discourage traffic use, particularly in urban centres.

The project has delivered a sophisticated tool to enable for the first time the explicit calculation of public health impacts arising from future energy strategies in the UK using an air quality model with an energy systems model. This represents a major improvement over previous damage cost approaches to assess the impacts of climate change policy and its influence on air quality.